The Need for Process-driven, Watershed-based Wetland Restoration in Washington State

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Abstract
The continued decline in the health of aquatic species and ecosystems indicates that something is dramatically wrong with our current approach to resource management in the Pacific Northwest. Causes for this lack of success fall into two general areas. First, very complex ecosystems have been over-simplified or dissected into individual parts to facilitate regulation and management. Second, existing regulations and recovery efforts typically focus on structural components at a site scale. Considerable evidence suggests that process-driven, watershed-based tools that look at multiple spatial and temporal scales need to be developed to provide the conceptual framework for organizing and coordinating management and recovery actions at the site scale. In 1994, Washington State Department of Ecology initiated a landscape-scale wetland restoration program to meet an objective of the Puget Sound Water Quality Management Plan. In 1998, an interdisciplinary technical team was assembled to build on this work in concert with emerging concepts in the literature to develop tools that help recover threatened and endangered salmon runs, improve degraded water quality, and address causes of increased peak flows and declining stream baseflow. This paper presents insights gained during development and initial implementation of these landscape-scale process-based assessment efforts.

Introduction
The Puget Sound region of Washington State is a unique and unparalleled ecological resource. This rich and varied ecosystem is the result of the region's great topographic diversity and the interactions of physical, biological, and chemical processes at many spatial scales. These processes create the ecological diversity and interdependent relationships that produce Puget Sound's abundant natural resources and striking beauty.

Contributing to the region's unique qualities are an equally diverse and abundant suite of wetland resources that include estuarine salt marshes, large forested floodplain wetland complexes, *Sphagnum* bogs, glacial kettles, rugged high elevation meadows, and extensive fens. The distribution and diversity of these aquatic systems are the result of local geomorphology, climate, and disturbance history (Naiman and Anderson 1997).

While impressive in their diversity and abundance, Puget Sound wetland resources are finite. As in other parts of the United States, agricultural, commercial, and residential development has resulted in a substantial loss of wetland resources. Estimates of statewide wetland loss vary from 33 to 50 percent, with Puget Sound experiencing losses to tidally influenced emergent wetlands in excess of 70 percent (Canning and Stevens 1989). One study documented wetland losses of over 95 percent in some urbanized areas (Bortelson and others 1980).

Adding to these extensive wetland losses is the very real threat of future resource degradation. At least three factors significantly threaten Puget Sound's natural resources:
1. The number and distribution of people.
2. The amount of resources they consume.
3. The waste they produce.

In 1950, Washington State supported 2.4 million people. Today, the state's population exceeds 5.6 million people and, if projections are correct, the states population will grow to 7.7 million by 2020 and 11 million by the year 2045 (Washington State Department of Natural Resources 1998). This level of population growth means that over the next 45 years, the State of Washington will add the equivalent of 29 new cities the size of Tacoma or Spokane (Washington State Department of Natural Resources 1998), and much of this growth will occur in the Puget Sound region.

This rapid growth, and land use decisions associated with that growth, has resulted in the listings of salmon and steelhead under the Endangered Species Act (ESA), water quality degradation to over 750 water bodies statewide (Washington State Department of Ecology 1998), increased peak flows in urbanizing streams, and a decline in some stream base flows. The troubling status of these key natural resources indicates that something is dramatically wrong with our current approach to resource management in the Pacific Northwest. It is clear that the existing regulatory framework and implementing agencies have fallen short of expectations (Governor's Salmon Recovery Team 1999).

Causes for this lack of success are open to debate and potentially numerous. It is becoming more apparent that a lack of watershed-based tools restricts development of a conceptual framework for organizing and coordinating recovery actions (Alder 1995; Angermeier and Schlosser 1995; Frissell 1996). I suggest two generalized problem areas:

First, the ecological context and nexus of natural systems is often lost as resource managers specialize in a single component of an ecosystem (e.g., wetlands, stream channels, lakes). This has resulted in very complex ecosystems being over-simplified to facilitate regulation and management. While classification systems have been essential in the study and assessment of individual resource components, they can lead to a level of confidence in specialization that impedes our ability to understand the system as a whole. For example, the alluvial floodplains of virtually all major river systems flowing into Puget Sound were once an intricate interconnected mosaic of main channel, side channel, wetland, forested riparian, and hyporheic systems that were constantly being reworked by natural disturbance factors within and outside of the channel migration zone. While substantial work has been done to study wetlands, riparian systems, stream channel morphology, and more recently the hyporheic zone (Naiman and Anderson 1997), ecologists are just beginning to see and understand the system as a whole (Naiman and others 1992). I suggest that resource managers must first recognize and understand the complex interactions of natural systems as a whole to establish the context for the detailed study of a systems individual resource components.

Second, the recurring need to address individual species (e.g., chinook salmon) or species guilds (e.g., migratory waterfowl) for economic or social reasons tends to direct resource managers to site-specific, structure-based components of a species habitat and not on the landscape-scale processes that create and maintain habitat structure. This has led to a dependence on engineered structure-based fixes to resource problems. Fisheries biologists in the Pacific Northwest have often focused research on site- or reach-specific habitat conditions and the productivity of important life stages of individual species of salmon or steelhead. An example of this type of assessment comes from the Salmon Recovery Planning Act (ESHB 2496) of 1998 that requires a limiting factors or reach-specific structure-based analysis of habitat bottlenecks for habitat restoration (Governor's Salmon Recovery Team 1999). While site-specific structure-based assessment is an essential component of a resource recovery plan, it is not the only essential component. A growing body of evidence indicates that assessing habitat-forming ecological processes at landscape scales (Beechie and Bolton 1999; Kauffman and others 1997; Montgomery and others 1995; Naiman and others 1992) establishes the needed context for directing assessment at finer scales.

As early as 1990, the Puget Sound Water Quality Authority (1990) called for the development and implementation of a watershed-based, non-regulatory wetland restoration program to assist in reaching the goal of restoring and protecting the biological health and diversity of Puget Sound (Puget Sound Water Quality Authority 1990). From the program's beginning in 1994, a conceptual framework for landscape-scale wetland restoration planning in Puget Sound was established (Gersib and others 1994), and methods development began in the 719-square-mile Stillaguamish River Basin (Gersib 1997) and refined in the Nooksack and Snohomish River Basins.

As implementation of the wetland restoration program progressed, it became clear that while wetland degradation was an important factor that adversely effected fish habitat and water quality and quantity, it was only one of sometimes many degradation factors that have cumulatively resulted in the current natural resource problems. Lessons learned from this program served as the catalyst for a broader interdisciplinary river basin characterization effort that looked more holistically at resource degradation and recovery.

This paper describes these two developing landscape-scale recovery tools and shares recommendations and lessons learned through their development and early implementation. The purpose of this paper is to stimulate thought and discussion that helps refine and expand existing landscape-scale process-based concepts for ecosystem recovery.

Watershed Assessment Elements

Washington State Department of Ecology (Ecology) has initiated two landscape-scale characterization efforts to support natural resource management decision-making. These initiatives are described here to establish the context for presenting lessons learned.

Puget Sound Wetland Restoration Program

The primary goal of the Puget Sound Wetland Restoration Program is to develop a landscape-scale wetland restoration program that assists natural resource managers in identifying wetland restoration sites having the greatest potential to address ecological problems in the river basin. To do this, a method termed '*wetland function characterization*' was developed that identifies potential wetland restoration sites and then ranks them based on their expected ability to perform key watershed functions when restored.

A local technical work team and a more general advisory group were used to:

a. Identify important ecological problems and community needs to be addressed.
b. Help develop function characterization models that predict each site's potential to perform a wetland function.
c. Provide insight and Geographic Information System (GIS) data sets for landscape scale assessment.

Aerial photo interpretation was used to develop a GIS coverage of potential wetland restoration sites and assign a series of attributes to each site. While attributes have evolved over the past 4 years, the overall objective has been to describe:

a. The current and historic hydrogeomorphic class of the wetland (Brinson 1993; Brinson 1995; Smith and others 1995).
b. The type of hydrologic and vegetative alterations at the site.
c. Land use.
d. Restoration potential based solely on existing development at the site.
e. Specific characteristics of the site that affect site functions (e.g., percent open water, evidence of groundwater discharge, area of unvegetated river bar).

For each river basin, a team of specialists with wetland expertise and knowledge of the area refined and, when necessary, developed new GIS-based rules that use landscape and wetland characteristics to predict which wetlands are likely to perform each of 18 wetland functions, when restored. Functions currently modeled include:

1. Temperature maintenance
2. Fecal coliform control
3. Sediment retention/transformation
4. Nutrient retention transformation
5. Groundwater nutrient retention
6. Flood flow storage and desynchronization
7. Base flow maintenance
8. Groundwater recharge
9. Amphibian diversity and abundance
10. Anadromous and resident fish diversity and abundance
11. Migratory water bird diversity and abundance
12. Aquatic diversity and abundance
13. Rare, threatened and endangered species diversity/abundance
14. Food chain support
15. Active and passive recreation

16. Outdoor education
17. Cultural significance/unique qualities
18. Shoreline stabilization

Model outputs are incorporated into a GIS coverage and searchable database from which it is possible to produce custom reports on high priority wetland restoration sites that address a particular watershed issue such as stream temperature.

An accuracy assessment of the aerial photo interpretation was conducted for both the Nooksack and Snohomish River Basins. During visits to 58 sites in each river basin, the same attributes assigned through aerial photo interpretation were independently assigned in the field. Consistency between aerial photo interpretation and the field assessment was determined and used to refine the methods. Function characterization model validation is planned but, as yet, unfunded.

Program implementation in three Puget Sound river basins serve as the foundation for our learning. The 719-square mile Stillaguamish River Basin was the initial system used to develop many of the landscape-scale wetland restoration concepts (Figure 1). This basin was followed by assessment in the 1624 square mile Nooksack River Basin and the 1909 square mile Snohomish Basin.

A GIS coverage and database were developed for the Stillaguamish and Nooksack River Basins that provides information on the location, size, and potential wetland functions provided by 1737 and 3513 potential wetland restoration sites, respectively. Work continues in the Snohomish River Basin were 5137 potential wetland restoration sites have been photo interpreted but is pending functional characterization. A methods document was prepared for the Stillaguamish Basin (Gersib 1997) and is being written for the Nooksack Basin.

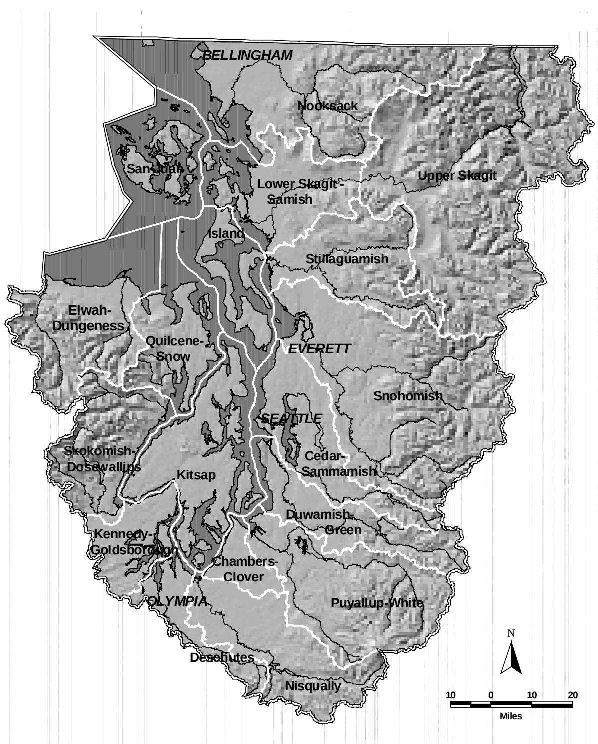

Figure 1. Puget Sound Catchments

River Basin Characterization

In 1998, an interdisciplinary technical team was formed consisting of a geomorphologist, hydrogeologist, fisheries biologist, two part-time water quality specialists, an ecologist, and a GIS analyst and technician.

The goal of this team was to develop and assess a landscape-scale process-based technical framework for evaluating human impacts to water quality, stream base flow, flooding, and anadromous fish habitat.

Our approach to river basin characterization is based on the following key assumptions:

1. Problems must be assessed at the scale in which they occur.
2. Assessment is needed at multiple spatial and temporal scales to provide the best opportunity to understand cause-and-effect relationships between human land use and their effects on water quality, water quantity, and anadromous fish habitat.
3. Ecological processes are the physical agents of landscape pattern formation and maintenance that create and maintain the physical, biological, and chemical features of aquatic resources.
4. Landscape-scale assessment should start at the largest appropriate spatial scale for the specific problem being addressed and advance sequentially through finer landscape scales and levels of analysis.
5. Restoring natural ecological processes results in a self-maintaining system, while simply replacing the structural components of a natural system is not self-maintaining.

Operating on the premise that the delivery and routing of water, sediment, large wood debris, nutrients/toxicants/bacteria, and heat are the key ecological processes that create and maintain structure and function in Puget Sound river basins, a pilot project was initiated in the 1909 square mile Snohomish River Basin in Washington State (Figure 1).

The Snohomish Basin was spatially subdivided into 62 sub-basins for analysis (Figure 2). Land use/land cover coverages were developed for the following three temporal scales:

a. Pre-European settlement using 1870's General Land Office surveyor data.
b. Current conditions using Landsat imagery.
c. Future build-out based on Growth Management Act planning.

Team members then used available data and existing technical literature to assess the comparative risk that human land use has altered or will alter each key ecological process at the sub-basin scale.

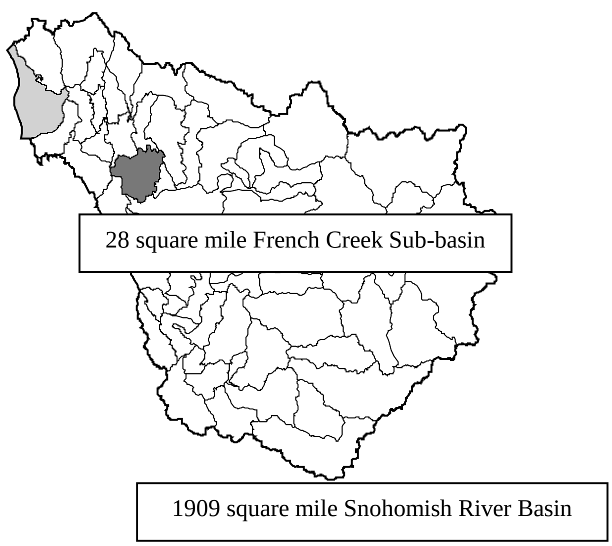

Figure 2. Example of river basin and sub-basin scales used in this paper.

Products of this work are a GIS coverage and database that displays the results of comparative risk assessments of key ecological processes in 62 Snohomish sub-basins. A document was developed that presents methods used in river basin characterization and examples of how results can be used to develop a recovery framework for the Snohomish River Basin (Gersib and others 1999).

Specifically, river basin characterization:

1. Provides a river basin-scale conceptual framework for ecosystem recovery.
2. Develops new information that supports decision-making at finer scales.
3. Establishes a foundational understanding of the river basin, that is, the core ecological processes that create and maintain ecosystem function, the effects of human development on natural processes, and the resulting water quality, baseflow, anadromous fish habitat, and flood storage/desynchronization functions.
4. Establishes general links between human development and a loss in river-basin function.
5. Helps resource managers understand process alteration in developed or managed areas of a river basin and the potential degree of process alteration under future conditions.
6. Describes pre-disturbance, current, and future conditions of the river basin, when possible.
7. Serves as a course sieve to identify sub-basins that warrant further analysis for preservation or restoration.
8. Minimizes potential for conflict associated with single-species management by focusing recovery efforts on the restoration of natural processes that create and maintain ecosystem health.
9. Provides a neutral platform for discussions between neighboring political jurisdictions that need to share in future landscape-scale protection and restoration efforts.

Program Integration

River basin characterization is used to predict where human land use has the greatest risk of altering key ecological processes at a river basin scale. We see this information the foundation that directs where assessment work will be completed at the sub-basin scale. The Puget Sound Wetland Restoration Program is one component of sub-basin scale assessment that provides essential information needed to develop cause-and-effect relationships resulting in a change in key processes. This integration also provides a level of efficiency in that potential wetland restoration site identification and function characterization is done only in targeted sub-basins rather than the entire river basin. Sub-basin assessment, in turn, provides the foundation that directs assessment of individual site functions and feasibility.

Lessons Learned

The development and initial implementation of the Puget Sound Wetland Restoration Program in the Stillaguamish, Nooksack, and Snohomish Basins and River Basin Characterization in the Snohomish Basin of Washington State have provided unique opportunities to apply concepts discussed conceptually in the literature, but rarely implemented at larger landscape scales. The following are lessons learned and insights gained through these landscape-scale efforts.

Issues of Scale

The scale of the problem dictates the initial scale of assessment. While recovery efforts are implemented through a series of site-specific actions, assessment must begin at the scale of the problem. This means if a water quality problem is from a point source, then the problem should be assessed at the site scale. However, if the problem is depressed anadromous fish populations in the Pacific Northwest, then analysis should begin at the Pacific Northwest scale and then move through finer scales of assessment. In the case of ESA listed Pacific salmon, the National Marine Fisheries Service has done this large landscape-scale assessment and subdivided the region into Evolutionarily Significant Units (ESU) for management and assessment at finer scales. I suggest that assessment at the site scale limits recovery to site-specific problems. Assessment at a watershed scale allows recovery opportunities at the watershed scale. Site-based "fixes" to landscape scale problems is analogous to random acts of kindness to the landscape that are not capable of addressing landscape scale problems.

Landscape-scale assessment should include multiple spatial scales. The need exists for more consideration of the scale or scales from which to manage natural systems (Haskell and others 1992; Franklin 1993). Richards and others (1996) support this by noting that habitats are influenced by factors operating at a number of spatial and temporal scales. River basin characterization demonstrates the value of a hierarchical decision-making tool. Initial work in the Snohomish Basin was used to direct assessment and recovery efforts to sub-basins having the greatest potential of human-induced process alteration. As more detailed assessments are done in these sub-basins, individual projects will be identified for site-specific assessment and implementation. Without this type of science-based hierarchical tool, assessment would be required in all 62 sub-basins or best professional judgement employed to select key basins for assessment. The cost and time required to do detailed sub-basin scale assessment work in all 62 Snohomish sub-basins would be prohibitive and best professional judgement has not proven to be an effective option based on the lack of success in resource recovery, to date.

River-basin characterization has shown that we learn different things at different scales. At a river-basin scale, course sieve characterization develops a foundational understanding of the river basin and the ecological processes that create and maintain functions important to people; assesses the comparative risk that human land use has altered key ecological process; and provides the short-term context for preservation and recovery actions until finer scales of assessment are completed. At a sub-basin scale, process-based assessment identifies areas and land use practices that account for the alteration of key ecological processes and establishes a list of priority areas for preservation and restoration. At a site or reach scale, projects are comparatively assessed for feasibility and functions gained that results in a preservation and restoration site priority list.

Work done by the Puget Sound Wetland Restoration Program to assess many potential wetland restoration sites is considered to be a sub-basin scale of assessment of wetlands. Ideally, once a river basin characterization has identified sub-basins to be targeted for sub-basin scale assessment, wetland restoration work would focus on those targeted sub-basins rather than the entire river basin. Landscape-scale assessment of potential wetland restoration sites facilitates the identification and comparison of many potential sites while establishing the context for how wetland restoration can be used to restore key ecological processes.

Landscape-scale assessment should include multiple temporal scales. As early as 1978, Wolman and Gerson (1978) noted that humans have altered many of the natural processes that control the form and development of landscapes, watersheds, and wetlands. To assess the comparative potential for process alteration, river basin characterization started with the creation of a pre-development land cover coverage using General Land Office surveyor data of vegetation from the early 1870s. The project plan was to compare this pre-development coverage with a current land use/land cover coverage. While this is an essential assessment step, it became apparent that, with the population growth projections for Puget Sound, a future land use/land cover coverage was needed to assess the effects of future development compared to current conditions. Based on long-term planning documents, required of local jurisdictions under the state's Growth Management Act, a future build-out land use/land cover coverage was developed. Using pre-development, current, and future build-out land use/land cover coverages, individual team members assessed the comparative risk of process alteration by sub-basin from pre-development to current conditions and from current to future build-out conditions. This assessment at multiple temporal scales has proved to be a powerful tool in the development of an overarching recovery framework for a river basin.

Look "big picture" first and then focus down. Planning at the landscape level is the only way we are going to avoid undesirable, if not unacceptable, landscape dysfunction (Franklin 1993). Because biologists are often trained to do site-specific work, we tend to collect and analyze data at that scale. Assessment at multiple scales is, in many ways, like running river gravel through a series of sieves. The coarsest sieve (river basin characterization) allows you to assess the largest pieces of aggregate. This in turn establishes the context for evaluating the medium-sized rock captured in the moderate sieve. And finally, the combined knowledge gained from the courser sieves allows improved comparison of the finest grains. By collecting data at the site or reach scale first, you are only capable of looking at the finest grains without benefit of its parent material.

A site- or reach-scale approach also restricts the ability of resource managers to identify core problems through an understanding of cause-and-effect relationships. For example, a perched culvert (the cause) results in a fish passage barrier (the effect). Replace the culvert and the true cause of the problem is addressed. Rarely are cause-and-effect relationships that straightforward. A more likely scenario occurs when biologists indicate that riverbed scour is a potential limiting factor for chinook on a river reach. The task of identifying limiting factors is monumental in its own right, but when the only available choice for resource managers is to correct alterations on the reach where scour is occurring, success becomes unlikely. Scour is not the core problem, but the effect of one or more ecological process changes that occurred upstream of the site. Scour may be the limiting factor for chinook production in this particular reach of river, but it is the symptom of a human-induced change in how the watershed delivers and routes water, sediment, and wood. Unless we begin to focus on the core problems, recovery efforts will not be successful.

Looking “big picture” means looking at ecosystem health rather than the health of individual parts (Franklin 1993). It also provides an opportunity to understand and assess the cumulative function of all wetlands in a river basin that may be different than the additive function of the individual wetlands themselves (Johnston and others 1990). Norton (1992) suggests five axioms of ecological management that create a framework for the assessment of ecosystem health by looking at ecosystem processes. Gaining an understanding of ecosystem health and where and how the system is compromised establishes the foundation for an overarching recovery framework that targets core problems.

Selection of the highest priority wetland restoration sites requires a landscape perspective. Past efforts have focused on assessing functions and values of individual wetlands. This requires a detailed site-specific assessment of physical, biological, and chemical attributes. The issue is one of efficiency. In the Nooksack Basin, nearly 5400 sites were evaluated, of which 3513 were determined to have restoration potential. The cost and time required to do site-specific function assessment on all 5400 sites is unrealistic and unnecessary, if a course sieve characterization approach is taken. While assessing functions at a site scale is ultimately necessary for the highest priority sites, a landscape scale assessment is needed to efficiently identify those high priority sites from the hundreds, even thousands, of potential wetland restoration sites in a river basin.

Wetlands in an Ecosystem Context

An assessment of function is only one component of a more comprehensive wetland assessment. Wetland ecologists need to move beyond function assessment in their comparative evaluation of wetlands. Wetland functions are the physical, biological, and chemical processes or attributes of a site (Adamus and others 1987, Hruby and others 1999). Ecological processes are the physical agents of landscape pattern formation and maintenance that create and maintain the physical, chemical, and biological attributes of a site (Gersib and others 1999). Site-specific function assessment is an essential tool to wetland ecologists at a site scale. However, without a landscape context provided by an assessment of the ecological processes, function assessment can be evaluating the symptoms of core ecological problems that can exist many miles from the assessment site. This requires that wetland function assessment be nested in a larger landscape context.

Through implementation of the wetland restoration program, we have begun to realize that landscape context is essential to function characterization. In Western Washington, a vast majority of precipitation moves as subsurface flow in a native coniferous forest-land cover. Surfical geology, topography, and land cover are important factors that dictate the amount, extent, and retention of sub-surface water. Large wetlands located on recessional outwash in the Nooksack Basin lowland have developed in remnant melt water channels carved in the outwash plain as continental ice sheets receded. These outwash plains are deep sands and gravels that support the basins largest surficial aquifer. This shallow aquifer discharges at topographic breaks providing the dominant water source for wetlands in this area. Immediately adjacent to the outwash plains are glacial marine deposits that have a near-impervious “hard pan” layer approximately 32 inches below the soil surface. In these deposits, precipitation percolates quickly down to the hard pan layer and then moves laterally to a topographic break where it discharges as a spring/seep or to a geologic break where it moves downward as groundwater. Wetlands occurring on glacial marine deposits are much smaller in size and receive groundwater discharge only during times of prolonged precipitation. This has resulted in wetlands on the outwash plain developing peat soils while wetlands on glacial marine deposits maintain mineral soils. Understanding this water movement, both above and below ground, as well as the effects of human land use on that movement, helps establish the landscape context needed to assess the functions that a wetland provides.

Functions are the product of ecological processes. It is an issue of scale. Assessing wetland functions at a site level limits a majority of the assessment to alterations at that scale. However, a wetland’s opportunity and effectiveness at performing a function are dependent not only on site-specific structural features but landscape scale processes as well. For example, a drainage ditch placed through a wetland is a site-specific structural modification that reduces water permanence and the site's effectiveness at providing summer rearing for juvenile coho salmon. An example of a landscape scale alteration is one where effective impervious surface and surface/sub-surface water withdrawals reduce summer low flows to the point where they restrict access to the site by juvenile coho salmon. In both cases, the wetland's effectiveness at providing habitat for juvenile coho salmon was lost, one resulting from a site-specific structural alteration, the other from the cumulative alteration of landscape scale processes many miles from the wetland site. Function assessment must move beyond simply comparing how one wetland functions in relation to another. Assessment should also be capable of answering the following questions: Is the wetland maximizing it's potential to perform each function? What are the core problems that are restricting the site from maximizing function performance?

Wetlands must be understood and protected as part of the larger landscape and not as a separate entity. Our goal should be to protect the autonomous, self-integrative processes of nature (Haskell and others 1992) rather than a select few parts. To do this, we must first establish the landscape context for wetland resources, the processes that influence them, how they influence processes, and how human land use effects each. This context is needed to understand the role that wetlands provide. Human activities must be understood in the larger context of self-organizing systems (Haskell and others 1992). Norton (1992) suggests that we choose between protecting features that are familiar to our culture, ecological features that support certain essential "services," or long-standing features that provide the geological context for ecological processes. Concepts learned through river basin characterization support the latter.

Wetlands in Ecosystem Management

Focus recovery efforts on preserving and restoring ecological processes. Understanding the processes responsible for shaping Puget Sound river basins and maintaining their biodiversity is fundamental to successful ecological management. Past recovery efforts have often focused on site-specific structure-based fixes to environmental problems. For example, increased stormwater runoff in urbanizing areas and development in the floodplain have resulted in increased flood damage along many Puget Sound rivers. Structure-based fixes such as higher dikes, straightened channels, and excavated floodways all treat symptoms, rather than the core problems. Until management focuses on the human-induced changes to the delivery and routing of water, recovery efforts will be elusive and short-lived. These short-term successes have led to the belief, in principle, that all processes can be submitted to human management by means of science and technology (Faber and others 1992). We are learning that this is not always a valid assumption.

Further, there is a growing body of evidence that structural "fixes" are rarely self-maintaining and serve, at best, as a short term fix to a long-term problem (Beschta and others 1994; Frissell and Nawa 1992; Elmore and Beschta 1989; Beschta and others 1991). Ehrenfeld (2000) suggests that when inputs of physical energy, in the form of water or wind movement, are dominating forces in structuring an ecosystem, then ecosystem processes should be the primary focus in developing restoration plans. In Puget Sound, water and ice have been the dominant forces that structure the ecosystem of this region. Alterations to the natural delivery and routing of water have contributed substantially to many of our natural resource problems. Only through the restoration of ecological processes will we begin to address these problems in the long-term.

One suggested approach adapted from the fluvial restoration objectives of the National Research Council (1992) includes the following objectives for landscape scale ecosystem restoration:

1. Restore altered ecological processes.
2. Restore natural landscape form, only if the restoration of ecological processes alone does not.
3. Restore natural plant communities, only if the restoration of ecological processes and natural landscape form does not.
4. Restore native plants and animals, only after steps 1-3 are completed and they do not re-colonize on their own.

In the Pacific Northwest, wetlands are a keystone natural resource that has an important role in how a river basin delivers and routes water, sediment, nutrients, large wood, and heat. By only assessing the functions of individual wetlands at a site scale, little consideration is given to their cumulative contribution to ecosystem health at landscape scales.

Landscape-scale recovery of ecological processes minimizes potential for conflict associated with single-species management. It is well documented that management actions developed at only the site scale and focused on only one species have the potential to adversely affect other species (Jackson and others 1995; Frissell and others 1997; Ehrenfeld, 2000). Meffe (1992) described attempts to restore individual salmon fisheries in the Pacific Northwest as “techno-arrogance” while Franklin (1993) noted that trying to conserve ecosystem diversity on a species-by-species basis is going to exhaust our patience, pocketbooks, and the time and knowledge available. Knowing this provides added pressure on natural resource managers when called upon to develop recovery plans for ESA listed species or management plans for economically important game species.

We are learning that the solution lies in our ability to focus on the natural habitat-forming processes rather than the habitat of a species. In the final rule governing the take of 14 threatened salmon and steelhead species in the Pacific Northwest, the National Marine Fisheries Service (2000) defines properly functioning condition as the sustained presence of natural habitat-forming processes that are necessary for the long-term survival of salmonids throughout the full range of environmental variability. By targeting the restoration of ecological processes that create and maintain habitat for all native species, the focus is on ecosystem health rather than individual species, reducing or completely eliminating the need for value judgements that place higher priority on one species over others.

Habitat management vs. the management of habitat-forming processes is clearly an issue of scale in both a spatial and temporal sense. Fast-changing human cultures are interacting with larger-scale, slow-changing ecosystems. There is a strong need to develop policies that allow human cultures to thrive without changing the life support functions, diversity, and complexity of ecological systems (Haskell and others 1992). I suggest this need can best be accomplished through the management of ecological processes.

An over-arching recovery framework at the river basin scale is an essential planning tool for integrating disparate natural resource management programs and initiatives. Through our work in the Snohomish Basin, it is apparent that the development of a technically sound recovery framework allows for both focused planning for salmon recovery, water quality, baseflow, and peak flow improvements and the integration of each into a multi-faceted recovery framework. In the Pacific Northwest, natural resource managers are expressing frustration with the myriad planning efforts underway. This planning and implementation is being done by different people, for different purposes, at different scales, with different timelines. Without an overarching landscape-scale recovery framework, these disparate planning efforts will remain uncoordinated. Work in the Snohomish Basin has demonstrated that the development of an overarching recovery framework for a river basin is possible. The challenge then is to develop and maintain the societal discipline needed to work in a coordinated fashion within the framework to maintain and adapt the recovery trajectory established.

Conclusions

Despite dramatic increases in effort, strong mandates, and massive expenditures for environmental protection over the past 20 years, the overall condition of natural ecosystems continues to decline (Karr 1995; Montgomery and others 1995). A growing body of evidence indicates that declines in ecosystem integrity are perpetuated by existing policies and traditional techniques that treat local symptoms of habitat damage and fail to address the root biological and physical causes of ecosystem degradation and population decline (Angermeier and Schlosser 1995; Montgomery and others 1995; Reeves and others 1995; Ebersole and others 1997).

For these reasons, natural resource management should begin to move away from a site-specific, structure-based paradigm for natural resource recovery and toward a more ecologically based landscape-scale, process-based approach. Three caveats are important. First, while resource managers are beginning to acknowledge that the existing structure-based paradigm is not working, much of the published literature on this new process-based paradigm is conceptual in nature and highly experimental in practice. Decades, rather than years, will be needed to evaluate its effectiveness. Second, while restoration will be the key driver for any natural resource recovery efforts, the preservation of intact functioning processes and systems should be the cornerstone of any resource recovery plan. Finally, while our understanding of basic linkages within natural systems and the effects of human land use on those linkages is still quite poor, it should not stop managers from merging what is known with professional judgement to advance our understanding of natural systems. The wetland restoration program and the river basin characterization project have sought to advance our understanding of resource assessment within the Puget Sound region. Efforts, like these, will require continued development and evaluation while new initiatives need to build on existing landscape-scale process-based assessments. If natural resource management truly implies movement toward desired end results, this transition in recovery paradigms must continue.

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